

## ***Gynaephora rossii* (Curtis) on Mt. Katahdin, Maine, and Mt. Daisetsu, Japan, and Comparisons to Records for Populations from the Arctic (Lymantriidae)**

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**Abstract.** Populations of *Gynaephora rossii* (Curtis), an Arctic and alpine species of Lymantriidae, were studied on Mt. Katahdin, Maine (45.5°N, 68.5°W; 1606 m) and on Mt. Daisetsu, Hokkaido, Japan (43.7°N, 143°E; max. 2289 m) during 15 single-day ascents. Larvae fed principally on ericaceous plants (*Rhododendron aureum* Georgi on Daisetsu, and *Vaccinium uliginosum* var. *alpinum* Bigelow on Katahdin) though roseaceous plants are reportedly eaten in the Arctic. In the laboratory, larvae from both locations fed on *Salix babylonica* L., and Maine larvae also fed on *Potentilla fruticosa* L. Development at the two locations appeared to require 2 or 3 years, whereas in the Arctic, it may take 10 years. Eggs, 1st-, intermediate-, and late-stage larvae, but not pupae, appear able to overwinter. At Daisetsu, egg masses (ave. 79 eggs, max. 139 eggs, n = 7) were positioned on upright woody stems, not on cocoons as reported for the Arctic. Coloration of the mature larvae of the alpine populations differed slightly.

Natural enemies include a parasitic tachinid, *Spoggosia gelida* (Coquillett), a first record outside of the Arctic, and an ichneumonid, *Nepiera* sp., both parasitic on larvae at Katahdin. An unknown ichneumonid pupal parasite (ca. 12% parasitism), a virus disease, and a predatory shrew, *Sorex* sp. occurred at Daisetsu. Populations of *G. rossii* fluctuated unpredictably from one season to the next. Defoliation of *R. aureum* was observed (Sept. 1975) at Daisetsu, and on subsequent ascents, the result was some host plant setback and mortality, therefore changes in floral composition.

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## Introduction

*Gynaephora rossii* (Curtis) is an unusual Arctic and alpine lymantriid, previously known as *Byrdia rossii* (Curtis (Ferguson 1978)). This species and a congener are the largest invertebrates living in the northernmost limits of vegetation in the high Arctic (Ryan and Hergert 1977) where they are subjected to environmental extremes. It also occurs on high mountain tops in lower latitudes. Because of the conditions in the Arctic and the probable ability of the insect to overwinter in any larval stage, the life span of *G. rossii* there may require many years. Thus this species, and a congener, "... are probably the longest-lived species of Lepidoptera known" (Ferguson 1978). Inasmuch as *G. rossii* lives in generally inaccessible Arctic or alpine habitats, relatively little biological information is available concerning this species. However, Downes (1962, 64, 65) cited *G. rossii* as particularly well adapted to climatic extremes of Arctic life.

In the Arctic, *G. rossii* occurs from Labrador, across Canada and Alaska in North America, and across eastern Siberia to the Ural Mountains in Asia (Ferguson 1978). In alpine habitats in eastern North America, it occurs on mountains in Quebec, on Mt. Katahdin, Maine (Brower 1974), on Mt. Washington (Dyar 1896) and Mt. Jefferson (Grote 1897) in New Hampshire. In the west, it is recorded from the high Rocky Mountains in Wyoming and Colorado (Ferguson 1978) and in Alberta by Ryan (1977) who illustrated the North American distribution. In Japan, only the Daisetsu Mountains (with several peaks over 2000 m) of central Hokkaido support this moth (Uchida 1936; Inoue 1956, 71); and further west, in the Sajon Mountains, southwestern Irkutsk, USSR, and mountains in Mongolia (Inoue 1965), populations are found of what appears to be the same insect. These Asian forms were described as a separate species, *G. lugens* Kozhanchikov, but this name has now been synonymized with *G. rossii* by Ferguson (1978).

We studied *G. rossii* during periodic ascents into alpine habitats of Mt. Katahdin, Maine USA (45.5°N, 68.5°W) and Mt. Daisetsu, Hokkaido, Japan (43.7°N, 143°E) and report here our observations. We also recorded parasites and other natural enemies, compared the 2 alpine populations, and considered the alpine populations in relation to available literature on the Arctic populations.

## Methods

Nearly all our information was obtained from direct field observations made during single-day ascents of the mountains. Between 1974 and 1978, Mt. Katahdin, elev. 5268 ft. (1616 m), was climbed 11 times (PWS 4 times, PJC 6 times, jointly 1) and Mt. Daisetsu, Max. 7513 ft. (2289 m), 4 times (PWS). Moreover, *G. rossii* larvae were so abundant during September (Katahdin 1974 and Daisetsu 1975) that a few larvae were returned to the laboratory and reared to obtain information on behavior,

feeding preferences, and parasitoids. Also at these times of abundance, the frequency of larval feeding on various plant species was recorded. Notes on abundance, behavior, and life stage were recorded whenever *G. rossii* was encountered. Photographs were taken of feeding larvae, eggs, plant host species, and the general habitats utilized.

## Results and Discussion

### Host Plants:

Various plant species have been reported fed on by *G. rossii* Tietz (1972) compiled a list for New England populations that included *Betula* sp., *Populus balsamifera* L., *Populus deltoides* Bartr. ex Marsh, *Salix* sp., and *Viburnum* sp. Those listed by Inoue (1971) included *Salix*, *Rhododendron*, *Vaccinium*, and *Empetrum*. In the Arctic, *G. rossii* was reported as feeding on *Dryas integrifolia* Vahl, *Saxifraga oppositifolia* L., *Salix arctica* Pallas (Ryan 1974), and *Saxifraga tricuspidata* Rottb. (Scudder et al. 1879).

When we observed the 2 alpine populations feeding and scored those plants being consumed by individual larvae, it appeared that a species of *Vaccinium* and a species of *Rhododendron* were most frequently eaten in mid-September in Maine and Hokkaido, respectively (Table 1). Indeed, ericaceous plants appeared to be a preferred food of both populations and at Daisetsu, when *G. rossii* populations were dense, the *R. aureum* at one site was almost completely defoliated. These feeding preferences are unlike those listed by Tietz (1972) for New England populations or for populations in the high Arctic (Ferguson 1978). Perhaps this is the result of

**Table 1**

Host plants fed on by *Gynaephora rossii* (Curtis) in two relict populations outside of the Arctic

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#### Mt. Daisetsu, Hokkaido, Japan\* (17 IX 75)

##### No. Larvae Feeding

22	<i>Rhododendron aureum</i> Georgi (Ericaceae)
6	<i>Phyllococe caerulea</i> Babington (Ericaceae)
6	<i>Geum pentapetalum</i> (L.) Makino (Rosaceae)
4	<i>Vaccinium vitis-idaea</i> Linnaeus (Ericaceae)
2	<i>Carex</i> sp. (Cyperaceae)
1	<i>Salix yasoalpina</i> Koidz. var. <i>neo-reticulata</i> (Nakai) Kimura (Salicaceae)

#### Mt. Katahdin, Maine, USA\* (14 IX 74)

31	<i>Vaccinium uliginosum</i> var. <i>alpinum</i> Bigelow (Ericaceae)
3	<i>Potentilla tridentata</i> Aiton (Rosaceae)
1	<i>Vaccinium vitis-idaea</i> var. <i>minus</i> Loddiges (Ericaceae)
1	<i>Empetrum nigrum</i> Linnaeus (Empetraceae)

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\*Plant determinations by Dr. Charles Richards, University of Maine, Orono, Maine and Dr. Koji Ito, Hokkaido University, Sapporo, Japan, for their respective areas.

adaptive shifts in host utilization in these confined relict populations. Generally, a shift toward increasing use of plants in Ericaceae probably would be the result of reduced plant diversity in the mountainous habitats where ericaceous plants are well represented (Tatewaki and Samejima 1959; Lamson-Scribner 1892). In the Arctic, Rosaceae and Salicaceae seem to be utilized most frequently. Brower (1974) collected larvae on *Potentilla tridentata* Ait. (as *P. trifoliata*) on Katahdin.

In a search for additional food plant information, we offered the laboratory held *G. rossii* a variety of related plants. Only *Salix babylonica* L. and *Potentilla fruticosa* L. were acceptable to these larvae. Also three varieties of *P. fruticosa* were tested, and Coronation triumph, Mt. Everest, and Jackmani showed decreasing acceptability, respectively. Ryan (1977) reared larvae in the laboratory on leaves of *Prunus*.

Ferguson (1978) suggested that *G. rossii* was a general feeder. We found larvae were limited to a rather narrow range of host plants by the restricted conditions of alpine environments. Our field evidence suggested that ericaceous plants were preferred (Table 1) despite the presence of other potential food plants (Tatewaki and Samejima 1959; Lamson-Scribner 1892).

#### Development:

Although the development of *G. rossii* larvae has not been studied in detail in any alpine habitat, Ohyama and Asahina (1971) suggested that it required 2 years on Mt. Daisetsu on the basis of evidence available from collected larvae. We also believe that 2 or 3 years are generally required. Oliver et. al (1964) hypothesized that any instar could overwinter at the onset of unfavorable conditions and that diapause was obligatory in the last instar. Our field evidence supported this first view since, on Daisetsu, we found mature larvae most frequently in September when fewer intermediate-stage larvae were present. Results of our laboratory rearing were contradictory to the second point on obligatory diapause. We found eggs in September which hatched when warmed up only slightly. Thus, there may be an autumn hatch of eggs, and both eggs and 1st-instar larvae may be present in mid-September directly before overwintering. These findings suggest that eggs and/or newly hatched, intermediate, and mature larvae observed in September were overwintering stages in at least one (Daisetsu) of the 2 alpine populations.

In the Arctic, the generation time is considerably longer. On the basis of weight calculations, Ryan and Hergert (1977) concluded that one generation required 10 years. From this information, Ferguson (1978) stated that *G. rossii* has the longest known development period for a moth. There is presently no precise data available concerning the number of instars; however, Ryan (1977) suggested 7 larval molts for *G. rossii* in Arctic populations. In any case the pupae are incapable of surviving temperatures of  $-20^{\circ}\text{C}$  (Ohyama and Asahina 1971). Then since ground surface temperatures were frequently lower than that on Daisetsu [min. temperature 5 cm below ground surface:  $-24^{\circ}\text{C}$  (Sakai and Otsuka 1970)], pupal survival during winter appears unlikely. This further strengthens the theory that overwintering in the last larval stage is obligatory.

The adults are known to emerge shortly after pupating: in early July in both Hokkaido (Inoue 1956) and Maine (Brower 1974). On Devon Island, Canada, adult emergence peaks during July but extends from June through August (Ryan 1977). Uchida (1936; species recorded as *Konokareha daisetsuzana* Matsumura) found adults present in August at Daisetsu.

### Behavior:

Adult male *G. rossii* are diurnally active in alpine habitats, are rapid flyers, and are attracted to females by a pheromone in both the Arctic (Oliver et al. 1964) and on Daisetsu (Kumata 1979). Although Ferguson (1978) states that females do not fly though they have fully-developed wings, this is apparently true only in the Arctic; since Kumata (1979) has observed female flight on Daisetsu. Flight, or at least active movement by females, is also suggested by the locations of egg masses. For example, on Daisetsu (24 IX 76), we found numerous egg masses on upright stems of several woody plants but none on the surfaces of the many cocoons in the same area. Egg masses were frequently found on cocoon surfaces at Devon Island (Ryan 1974). Also the maximum number of eggs in 7 masses at Daisetsu was 124, but the average was only 79. Thus it is likely that the females deposited more than one egg mass. Ryan (1977) recorded a mean of 139 eggs ( $n = 23$ ) per mass at Devon Island though a single female produced 240 eggs. No eggs were found on Katahdin.

Newly-hatched larvae at Devon Island spun silk and dangled from supporting vegetation (Ryan 1974). When similar larvae from Daisetsu were held in the laboratory, no silk production could be detected, even when we attempted to induce ballooning by blowing larvae off a substrate. Newly-hatched larvae from Maine were not available for similar tests.

On Daisetsu (10 VII 78), only one intermediate-stage instar could be found, and this one was well concealed at the base of matted alpine vegetation. It was not visible unless one parted the vegetation. This larva was removed and placed on the surface of the vegetation in full sunshine at midday. It immediately crawled downward to a resting position similar to that from which it had been removed. This was done repeatedly with the same results. Then the larva was placed on vegetation completely shaded by an embankment. It remained there for over 15 minutes. Temperatures were not recorded but it was evident that solar warming of the larva resulted in evasive behavior. Perhaps during summer days, temperatures can exceed an undetermined threshold above which larvae seek a cooler niche and become inactive. Such intolerance and avoidance of certain warm temperatures, may explain why no other larvae were found on this particular trip.

On another trip to Daisetsu (17 IX 75), mature larvae were numerous and active during midday when the temperature was 11°C. Many were seen walking over stones or barren ground and were actively feeding on suitable vegetation. Possibly in an alpine habitat where winter comes early, midday hours provide the only temperatures suitable for activity. At night (at ca 6000 ft elevation in Hokkaido), freezing conditions occur in September.

On Katahdin (14 IX 74), late-stage larvae were seen feeding and moving over the vegetation at temperatures ranging from 5.7 to 7.5°C.

### Natural Enemies:

At Katahdin on 20 VII 74, we found 4 estimated 3rd-instar *G. rossii*. One day later, a larva of *Nepiera* sp.<sup>3</sup> (Hymenoptera: Ichneumonidae) emerged from one of the moth larva and pupated. The adult parasitoid subsequently developed but died while attempting to emerge from its cocoon. Also larvae collected 14 IX 74 at Katahdin produced several puparia that eventually emerged as adult *Spoggosia*

<sup>3</sup>Identified by R. C. Carlson, SEL, IIBIII, AR, SEA, USDA, Beltsville, MD 20705.

*gelida* (Coquillett)<sup>4</sup> (Diptera: Tachinidae). This represents a new North American distribution record for this species outside of the high Arctic. These maggots emerged from mature moth larvae or pre-pupae already within a cocoon and at least 3 puparia were recorded from a single host. Later when we dissected 8 nearly mature *G. rossii* that lived in the laboratory to 8 III 75, we found 6 presumed *S. gelida* maggots (2 each in 3 hosts). The maggots were small (mean 2.2 X 1.3 mm), distributed evenly from the mesothorax to the 8th abdominal segment, and positioned internally just beneath the dorsal integument. A small orifice to the respiratory funnel was visible externally when setae were removed.

On Daisetsu, 17 IX 75, the larval population showed definite signs of a viral disease epizootic. Dead larvae placed in a vial disintegrated and a whitish precipitate characteristic of virus was present. It was not determined whether this virus was a NPV or CPV. Also when many cocoons collected on the same date were opened, 12.8% of 78 pupae had been killed by a pupal parasite thought to be a large ichneumonid similar in habits to *Coccygomimus* spp. based on the emergence hole. No specimens have yet been obtained.

Evidence of predation on *G. rossii* was found when we examined the stomach contents of a shrew (*Sorex* sp.) found dead on Daisetsu 24 IX 76. The stomach contained pieces of larvae (prolegs, integument, and setae) of *G. rossii*.

#### Populations:

Little information is available concerning *G. rossii* populations because of the inaccessibility of its natural habitats. Also, when one hikes through these mountainous areas, only scattered individual insects are usually seen. However, at one time on Katahdin (14 IX 74), mature larvae were so numerous they were often trampled as hikers moved along the hiking trail. It was at this time that we collected 26 larvae for rearing to assess parasite levels. Of these, 19 pupated, 12 adult *G. rossii* emerged, and 11 *S. gelida* emerged from those that did not pupate. The 7 larvae that died were dissected, examined internally, and several more maggots, presumed to be this same tachinid, were found. Thus *S. gelida* caused significant mortality. Ryan (1977) found *Gynaephora* cocoons (he did not distinguish between 2 species) to be 17% parasitized, with a mean of 4 flies/host.

*Gynaephora rossii* were rather plentiful on Katahdin in 1974. However, the junior author made 5 ascents during the 1975 season (24 V, 19 VI, 7, 17, 28 VIII) and found only one live pupa (19 VI). This scarcity reflects the unpredictability of populations from one season to the next and may indicate a cyclic appearance of any given life stage because of the extended period of larval development.

Meanwhile, on Daisetsu (17 IX 75), larvae were quite abundant in areas with sufficient vegetation. One 3 x 8-m plot had at least 150 larvae, many actively feeding. This density was sufficient to cause nearly complete defoliation of plants within this limited area, especially *R. aureum*. Subsequent observations at the same site indicated that this was not a common occurrence, which again suggests that populations fluctuate dramatically and may even be cyclic, not infrequent for many lymantriid species. The result of the observed outbreak in 1975 in this delicate alpine habitat was that in 1976 and 1978, the *R. aureum* plants were in poor condition. Some plants had sparse foliage, and others were dead. Probably it will

<sup>4</sup>Identified by C. W. Sabrosky, SEL, IIBIII, AR, SEA, USDA, Beltsville, MD 20705.

take many years for this particular vegetation to completely recover from the effects of defoliation by *G. rossii*.

#### Notes from Field-Collected Material:

A total of 26 larvae obtained at Katahdin on 14 IX 74 were returned to the laboratory for rearing. The mean live weight of these larvae was 0.389 g. In the laboratory, the larvae were divided into 6 groups (held at 5, 15, or 23°C in a 16L:8D photoperiod or in complete darkness). At 5°C no feeding occurred on *S. babylonica* or *P. fruticosa* leaves, and photoperiod had no apparent effect. Generally larvae were inactive, though they moved slightly. When these same larvae were warmed to 15°C on 25 XI, they spun silk cocoons. They were moved to 23°C on 2 XII. The 5°C temperature apparently prohibited silk spinning but did not completely stop movement though the temperature was probably close to a lower threshold for activity.

Larvae initially held at 15°C (from 18 XI to 4 XII) fed only slightly (measured by frass production), but silk spinning was evident in a number of dishes. This production of silk did not take place during normal feeding; it commenced just before molting to the pre-pupal stage. On 4 XII these larvae were moved to 23°C, feeding was more evident, and cocoon formation began 18 XI. By 1 XII, one female *G. rossii* emerged before 19 XII and 5 *S. gelida* adults emerged from 2 to 13 XII. Duration of the pupal stage at 23°C required 14 days for 2 moths and 8-10 days for the *S. gelida*.

It is significant that development of *G. rossii* continued uninterrupted after the September collection even though 23°C is not typical of ambient temperatures of the normal environment. Oliver et al. (1964) suggested that obligatory diapause probably occurred during the final instar, but our experience suggests that this is not true. Apparently, development may continue throughout any larval instar so long as temperatures (and probably photoperiod) remain favorable for development. In fact, on Daisetsu we recorded active feeding at 11°C and on Katahdin at 5.7 to 7.5°C.

One pupa collected on Katahdin 19 VI 75 emerged in the laboratory on 23 VI and produced some infertile eggs 2 days later. This seems to indicate that at Katahdin, adult emergence would occur in late June and likely July. Ferguson (1978) gives emergence dates 4 to 28 VII for adults collected in the southern alpine habitats.

#### Biological Comparisons:

Subtle differences were apparent among these widely separated *G. rossii* populations. Larvae at Katahdin were a more slate-colored gray than the more nearly brownish-gray larvae from Daisetsu. Also Ryan (1974b) noted that mature larvae forwarded to him from Katahdin had a different appearance than those from Devon Island and were smaller than mature Arctic larvae. For example, in a collection of 156 larvae of *Gynaephora* spp. (may include *G. groenlandica* (Homeyer), Ryan (1977) recorded a mean live weight of 630 mg; a similar figure for 20 larvae collected 13 IX 74 at Katahdin was 390 mg. Larvae from Daisetsu were not weighed but appeared to closely approximate those for Katahdin. In addition, coloration of some of the secondary setae on the thoracic tufts differed noticeably. Ferguson (1978) described these setae as "bright sulphur yellow". These same setae on living larvae from Katahdin were lemon yellow and on Daisetsu more reddish-orange. Ryan (1974b) noted similar distinctions between Katahdin and Devon Island larvae and stated that the latter were more orange. Elsewhere Ryan

(1974a) stated that Arctic specimens were black and orange as Curtis (cited in Scudder et al. 1879) had first recorded.

Adult *G. rossii* were compared by H. Inoue (1978) in an effort to clarify similarities between *G. rossii* and *G. lugens* Kozhanchikov. He found slight differences when he compared a valve from the genitalia of a male from Katahdin with ones from Daisetsu, but he examined too few specimens to reach a definitive conclusion. Ferguson (1978) concluded that *G. lugens* was a synonym of *G. rossii*, and he noted marked geographical variation among arctic specimens. This morphological variation is apparently even more pronounced when one is comparing individual insects from wider geographical locations.

There were other differences between the Arctic and alpine populations as summarized in Table 2. Foodplants for the alpine populations were species in the Ericaceae; plants in the Rosaceae and *Salix* are reportedly utilized in the Arctic (Ryan 1974; Ferguson 1978; Scudder et al. 1879). Also females appear to have evolved different oviposition behaviors: in the Arctic, they deposit many eggs on the surface of the cocoons from which they emerge (Packard 1877; Ryan 1974). At Daisetsu, eggs were positioned almost without exception on low upright twigs (often dead) of woody shrubs (Table 1 gives species) and not directly on or associated with cocoons, which were found lower in the vegetation mat at the same site. The masses were in irregular naked clusters often completely surrounding the stem and sometimes 3-4 layers deep.

It is not surprising that there are numerous differences among populations of the same species over widely divergent geographical locations (Maine, Hokkaido, and the Canadian Arctic), though all have similar extremes in environmental conditions. Probably spatial isolation of the 2 relict populations and the Arctic population has allowed evolution to work independently since the last glacial retreat. It is only a matter of time until genetic drift will have progressed to such a degree (if it has not already done so), that these populations would no longer interbreed if they were ever reunited.

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Table 2  
Synopsis of differences (morphological, behavioral, and recorded natural enemies) among 2 alpine relict populations and the Arctic populations of Gynaephora rossii

	Mt. Katahdin, Maine	Mt. Daisetsu, Hokkaido, Japan	Canadian & Alaskan High Arctic
	U.S.A.		
Coloration of mature larvae:	Slate-Gray Lemon-Yellow	Brownish-Gray Reddish-Orange	Black <sup>a</sup> , Orange <sup>a</sup> , <sup>b</sup>
Oviposition Sites:	Unknown	Upright Woody Stems	Cocoon Exterior <sup>c</sup>
Food Plant Genera:	<u>Vaccinium</u> <u>Potentilla</u>	<u>Rhododendron</u> <u>Phyllococe</u>	<u>Saxifraga</u> <sup>d</sup> <u>Salix</u> <sup>d</sup>
Natural Enemies:	Parasites* <u>Nepiera</u> sp. (Early L)	<u>Ichneumonid</u> sp. (P)** <u>Geum</u>	<u>Spoggosia gelida</u> (L) <sup>b</sup> <u>Rogas</u> sp. (L) <sup>b</sup> <u>Pterocormus byrdiae</u> (P) <sup>e</sup>
Predators:		<u>Sorex</u> sp.	
Diseases:		Virus	
Source/Reference:	Present Study	Present Study	<sup>a</sup> Scudder et al 1879 citing Curtis <sup>b</sup> Ryan 1974, 1977 <sup>c</sup> Packard 1877 <sup>d</sup> Ferguson 1978 citing others <sup>e</sup> Krombein et al 1979 citing Heinrich 1956

\* Letter designates host stage attacked, L-larvae, P-pupae. \*\* Based only on evidence of pupal remains since a Coccygomimus-like parasite had emerged from 12% of G. rossii pupae but no specimens were observed.

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